Calc/Solve Release Notes

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This is the first release of solve in several years. Over 150 subroutines have changed since the last release. Some of these are minor changes made so that the routines would compile under gfortran. Other changes were more extensive since the involved new features and the interface to the new VLBI format. In addition there are several entirely new programs. Because of this it is impractical to list all of the changes in detail. Instead this note summarizes the important changes.

1   MAJOR UPGRADES OF EXISTING PROGRAMS.

1.1   CALC 11

This version of calc includes the latest IERS standards. This includes:

- IAU2006/2000 Precession/Nutation.
- JPL Ephemeris DE421.
- High frequency polar motion and UT1 corrections for libration and ocean tides.
- Ocean loading: Hardisp model (342 constituent tides).
- Pole tide: New mean pole offsets.
- Ocean pole tide loading model.

Instructions on how to use calc11 can be found in the distribution at $MK5_ROOT/help/calc11_how_to.txt.

Calc11 requires the following a prioiri files which are in $MK5_ROOT/apriori and included in the release.

- blokq.c11.dat - site positions, source positions, TPX07.2 ocean loading coefficients, and ocean pole tide loading coefficients.
- DE421_little_Endian (or DE421_big_Endian) – new JPL ephemeris.
- tilt.dat – antenna tilt file .

In addition Calc11 needs

- ut1ls.dat – the leap seconds file.
- A 'ERP' format EOP, usually updated daily such as usno_finals.erp.

1.2   DBEDIT

Dbedit was modified to be compatible with the latest versions of hops, the hops library, and difx2mark4, and to correct a few bugs. However, dbedit does not yet fully support VGOS broadband sessions. Some updates to the output are still needed for 64 channel data and will be made when we get new broadband data.

1.3   SOLVE

This version of solve has many big fixes and enhancements.

The following lists some changes that should be transparent to the user. That is, you don't need to do anything different to use them.

- Ionosphere. The sigmas of the ionosphere correction are correlated with the sigmas of the X-band and S-band delays. The previous version of solve did not correctly take this into account when computing the sigma of the ionosphere corrected delays.
- Ionosphere. It turns out that solve was using two different routines to calculate the ionosphere correction—one in interactive mode, and one in batch mode—and they did things slightly differently.
- Finer segmented parameter resolutions. Wet zenith delay, gradient, and clock parameters can be estimated with intervals as short as 2-3 minutes depending on the session.
- SINEX file for a TRF/CRF solution. File can be generated that includes source coordinate parameters.
- Automatic parameterization. Solve has the option to automatically reparameterize solutions. It does this when it does not have enough data to estimate some parameters, typically baseline clocks. In some situations after reparameterization there were more parameters then before—that is solve would turn on some baseline clocks that were previously off. This has been fixed so that if a parameter is off it will stay off.

The following are enhancements to solve. To use these you must modify your control file. Below is a summary. These are discussed in more detail in another section.

1. Use of vgosDB as a replacement for superfiles. This version of solve can use the vgosDB format in interactive mode.
2. New options for WEIGHTS command. Previously you needed to have weights for the exact version of the session you were using. Solve has been modified so that solve can use the weights of a version that is close to the one that you are using.
3. Correlated noise. Solve can use station-dependent correlated noise in the analysis. The only limitation is that 'fast-mode' must be turned off.
4. Additional debug info. Solve can be prompted to output additional information.
5. Gradient mapping functions. Chen&Herrring style a priori gradient mapping function and gradient partial are available along with the older Davis&MacMillan version.
6. External troposphere modeling files. Solve can read external files that provide, on a scan-by-scan basis, the a priori slant delay, mapping functions, and gradient mapping functions.
7. External met data. Solve can read external met data. Currently it just uses the temperature data from these files to compute thermal deformation.
8. External site displacement files. Solve can read and use external site-displacement files. These files are in ASCII format. This can be used to incorporate known station displacements due, for example, to loading effects.

2 NEW PROGRAMS:

2.1 NUSOLVE

This is a replacement for interactive solve. nuSolve can read and write Mark3-database format, and read and write vgosDB format files. The software is able to perform all necessary operations for processing of a newly available VLBI session:

- compute ionospheric corrections from dual channel observations;

- performs ambiguity resolution in automatic and manual modes;
- detect and take into account clock breaks;
- make LSQ estimations of the following parameters: clock functions, zenith delays, stations positions, source coordinates, antenna axis offsets, polar motion offsets and rates, Earth rotation and rate, angles of nutation, baselines clock offset and vectors of baselines.
- eliminate outliers;
- perform data reweighting.

The software is written in the C++ programming language and has a modular structure. It has practically all of the functionality of interactive SOLVE and, in addition, a modern graphical user interface. We have used this at GSFC for the last 18 months in the analysis of R4s and intensives.
This is a first public release of nuSolve. We welcome comments and suggestions on how to improve this software.

2.2   Up11

Replaces up10. This is a Python script that has options to run calc11, create superfiles, create vgosDB format files (superfile replacements), update a Solve/Globl arc list, and/or delete the calc11 database version.

3   ~~openDB~~ vgosDB format

Why the cross-out? As Leonid Petrov pointed out in an email to IVS-Analysis, the name **openDB** is already taken. Although this probably would not be a problem, and to avoid any confusion, we decided the change the name of the new format to **vgosDB**. A quick web-search indicates that no one else is using vgosDB, and I doubt they well.

This release of *solve* allows the use of vgosDB files as a replacement for superfiles—that is you can use vgosDB files in the global mode of solve.   Timing tests done at Goddard show that for large sessions—CONT08, CONT11, the RDVs—vgosDB can run up-to twice as fast as using superfiles. For smaller sessions it runs a little slower. If you are doing a global solution using all 24 VLBI sessions there is little difference in total runtime between using superfiles and vgosDB.

nuSolve can read and write a vgosDB session, analyze the session, perform data editing and ionosphere calibration, and write out an updated vgosDB session.

3.1   db2vgosDB

db2vgosDB is a utility that will create a vgosDB session from a Mark3 database. The source code is in $MK5_ROOT/utils. Typing db2vgosDB without any arguments gives the following:

```
db2vgosDB usage:
  db2vgosDB database <ver> </update> </VGOS_DIR=vgos_dir>
    OR
  db2vgosDB arclist </update> </VGOS_DIR=vgos_dir>

   If ver is absent, will use latest version.
   /update            only create vgosDB if wrapper is missing for session
   /VGOS_DIR=vgos_dir  specifies output directory. If absent will look in environment.
```

For example, if you enter the command:

```
db2vgosDB 2013a.arc /VGOS_DIR=/500/vgosDB
```
The program will read in the arcfile 2013a.arc and create vgosDB format files under /500/vgosDB.

You can also convert a single Mark3 database to the new format:
```
db2vgosDB 10JAN04XA 4 /VGOS_DIR=/500/vgosDB
```

You must specify the vgosDB directory. This can be done at runtime, or by setting an environment variable:
```
Setenv  VGOS_DIR /500/vgosDB
```

4   MISCELLANEOUS.

4.1   USER PARTIAL
In modifying solve to use the vgosDB format we had to change the interface to the userpartial. An example userpartial program can be found at: $MK5_ROOT/example/userpart. If you have been using the standard User_partial template all you will need to do is replace your "userpart.f" by the "userpart.f" in this directory.

4.2   INTEL FORTRAN COMPILER.
This version compiles and runs under the latest Intel compiler. Although the calc/solve executables are compiled as 32-bit code we have successfully compiled and run the software on both 32-bit and 64-bit Linux operating systems.

4.3   COMPILATION UNDER GFORTRAN.
We are in the process of modifying calc/solve that it will compile and run under gfortran.   We have successfully compiled in excess of 98% of the code under gfortran. The remaining 2% involves subroutines that use special 'tricks' to do things that Fortran could not do at the time was written. To convert these to gfortran is not straightforward and will require some thought.

Many of the changes made to ensure that the code would compile under gfortran were minor syntactical changes. However we also found and fixed many sleeping bugs. Examples include treating logical variables as integers, and vice-versa, uninitialized variables, etc.

We hope to finish this project and have a version of calc/solve that will run under gfortran by the end of the year.

5   MODIFYING THE CONTROL FILE TO USE SOLVE ENHANCEMENTS.

This section contains detailed instructions on how to use the new features in solve.

5.1   VGOSDB FORMAT
The batch mode of solve can use the vgosDB format.

To do so include something like the following line in the $SETUP section

```
VGOSDB_DIR /500/vgosDB
```
Here `/500/vgosDB` is the directory where the vgosDB files are stored.

5.2 WEIGHTS

5.2.1 Nearest Weights
It may happen that you want to run a solution for a version of a database that you don't have weights for. Previously you would either have to modify the weight file to include weights for the particular version. We modified solve so that it can use a value for a version that is close (for example, use the weights from version 6 for version 7.). All you have to do is add "NEAREST" at the end of the weight line in the $SETUP section:
```
WEIGHTS   REQUIRE   glo_baseline.wgt BY_BASELINE NEAREST
```


5.2.2 Zero Weights
In some instances you don't want to have any additional weights—either from the database or an external file. Previously the only way to do this was to make a weight file with all of the weights 0. We modified solve so that you can use an existing weight file and put "ZERO" on the end of the WEIGHTS line:
```
WEIGHTS   REQUIRE   glo_baseline.wgt BY_BASELINE ZERO
```


5.3 CORRELATED NOISE
Solve has the ability to model station dependent correlated noise.

To use this feature add the following line in your control file in the $SETUP section.
```
APRIORI_OBS_CORR REQUIRED noise_wt6.txt
```

Here noise_wt6.txt is in the $SAVE_DIR directory. This file contains information about the station dependent noise. There are two options for this file.   A global noise file applies the same noise to all sessions and stations. It looks something like this:

Global noise file
; this is a comment.
global full map 6

The second token is either "diag" or "full". In the first case noise is added to the diagonal of the covariance matrix. In the second case noise is also added to the off-diagonal terms. The third token indicates that the noise is proportional to the mapping function, and the last gives the size of the noise. The kind of noise recognized are MAP, CLOCK (=constant), SINEL, COTEL, and DMAP/DEL, the last being proportional to the derivative of the mapping function.

You can have several kinds of noise in the same file:

Global noise file with two kinds of noise.
global full map 6
global diag clock 10

The noise file can also be session and station dependent. An example is given below.

Session dependent noise file
; One value for each station in the solution.
;   1 2 3 4 5 6 7 8 9 10 11 12 13 14
$11SEP15XA full map 6 7 8 9 3 4 5 6 2 3 5 5 5 5

We have found that on many datat sets (the CONTS; R1s and R4s; RDVs) using the first example given above (global noise file, mapping function dependent correlated noise with amplitude 6 ps). The results are even better if you have no additional weighting, e.g., use the "ZERO" option I the WEIGHTS line described previously.

5.4 ADDITONAL DEBUG INFORMATION
By including some or all of the following lines in the $SETUP section solve will output additional information:
```
DEBUG_OUTPUT LOOP_CALIB
DEBUG_OUTPUT LOOP_PARTL
DEBUG_OUTPUT LOOP_FLYBY
```

This information will be put in the file $WORK_DIR/DEBUGxx, where xx are the users initials. Each of these options is independent. For example, LOOP_CALIB will give information calibrations applied on an observation by observation basis, and similarly for the other options.

5.5 GRADIENT MAPPING FUNCTIONS
Chen&Herrring style a priori gradient mapping function and gradient partial are available along with the older Davis&MacMillan version.

5.5.1 Chen&Herring Gradients
Users can specify the Chen&Herring constants for the a priori gradient mapping function and the gradient partial separately (e.g., for hydrostatic and wet gradients) in the $PARTIAL section of control file:
```
SET GRADMAP CH Capr Cpart
```
where Capr and Cpart are the values of C in the Chen&Herring mapping function You can specify values for the a priori gradient mapping function and the partial. Nominally, C=0.0032.

5.5.2 Davis&Macmillan Gradients
To use the Davis&MacMillan gradient include the following line in the $PARTIAL section.
```
SET GRADMAP DM
```

5.6 EXTERNAL TROPOSPHERE FILES.
The Goddard VLBI group developed an interface to solve to use external files to model the troposphere. These files have the extension 'trp' and there is one TRP file for each session. For example, for 10JAN04XA the associated trp file is 10JAN04XA.trp. For each station and scan these files contain the a priori delay, a wet mapping function, and a gradient mapping function. The files are organized by year and session:

trp_dir/	1979/	
	…	
	2010/	10JAN04XU.trp, 10JAN04XA.trp….
	2011/	
	2012/	

This scheme gives great flexibility. As models improve you do not need to modify solve. All you need to do is generate new TRP files that incorporate the models. We originally used external TRP in order to use the VMF mapping function in solve. More recently we have used it to incorporate the results of ray-tracing.

5.6.1 How to use TRP files in solve.

In the $MAPPING section add a line like the following:

```
EXTERNAL_TRP_DELAY    REQUIRE DIRECTORY /500/vmf1_tot
```

In the $CALIBRATIONS section disable NMF

```
DISABLE   NMFDRFLY
```

In the $PARTIALS section disable NMFWTFLY

```
SET NMFWTFLY    OFF
```

5.6.2 Making TRP files

The utility make_vmf_trp_files located in $MK5_ROOT/utils/make_vmf_trp will generate trp files.

5.7 EXTERNAL MET DATA

Solve was modified to enable it to use temperature data contained in external files for use in thermal modeling of the antenna. To do so add something like the following line to the $MAPPING section

```
ANTENNA_THERMAL     MODEL EXTLAGGED /500/g-ecm/met/ 2. 6.0          \
    /500/oper/solve_save_files/antenna-info_modwe.txt INSITU NONE
```

Here `'/500/g-ecm/met/'` is the directory where the met data is contained. This directories contains files named something like: /500/g-ecm/met/1993/1993001.ecm1_r which contain the met data. These files are available via ftp at: http://lacerta.gsfc.nasa.gov/met/

The '2. 6.0' in the above line denotes the time lag for the steel and foundation of the antenna respectively.

5.8 EXTERNAL SITE DISPLACEMENT FILES

Solve can read and use site-displacement files that are in ASCII format. These can be used to model station displacement due to loading or other effects. You can specify up to 10 different displacements. Solve will read the displacements in and then add them up. To specify a displacement add a line like the following in the $MAPPING section:

```
DISPLACEMENT HYDROLOGY BY_TIME /home/derik/series/hydrology/
```

The second keyword (HYDROLOGY above) is purely descriptive and has no effect on processing. The "BY_TIME" indicates that the data in the files is time dependent (as opposed to being scan dependent—BY_SCAN). The last token "/home/derik/series/hydrology/" is the top level directory where the data is stored. This directory is organized by year, e.g:

```
ls /home/derik/series/hydrology
1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989
```

Within each year are files that contain displacement data for a given station:

```
ls /home/derik/series/hydrology/1991
AIRA_1991.txt    CTVASTJ_1991.txt  GBT-VLBA_1991.txt ….
```

The indivual files look like:

```
bootes: /home/derik/series/hydrology/1987>> head ALGOPARK_1987.txt
4.68100000e+04 -3.13216630e-03 -1.43586650e-04 -1.24132150e-04
4.68410000e+04 -3.72581790e-03 -1.38350140e-04 -1.34959620e-05
4.69000000e+04 -2.27147160e-03 -1.99261210e-04 -2.74881500e-04
```

The columns are MJD and UEN displacement in millimeters.

Solve will find the stations that are in the session and read in the appropriate files. It will use splining to interpolate the displacements to the epoch of the obsevations.

6   VGOSDB PROGRAMS AND UTILITIES

Originally we planned on releasing a whole set of tools that worked with the vgosDB. However, these were originally designed to work with openDB format files. Although these are essentially the same format we were concerned that the name change might break some internal logic in these programs. Rather than delay the release to do further testing, we decided to do release these utilities separately after they had been thoroughly tested.

The following describes the vgosDB programs that we will release separately in March or April of 2014.

- vgosDBmake. This program will make a vgosDB session from correlator output files. This is the counterpart to dbedit. The vgosDB session that it creates will include both X-band and S-band data.
- vgosDBcal. This program corresponds to dbcal. It reads the log files and adds cable and met data to the vgosDB session.
- vgosDBcalc. This program corresponds to calc. It will read an vgosDB session file and add in values computed by calc.

There are also utilities to convert exisiting Mark3 databases into vgosDB format sessions.

- vgosDBmerge. Since the X-band databases only contain some of the S-band databases there was a need for a utility to merge in the missing S-band data. This is done by vgosDBmerge.

In addition to the above:

- vgosDBview. This program allows you to open and view vgosDB sessions. You can list data items in a tabular form, or plot one data item versus another. You can save plots in various forms—jpeg, pdf, etc. You can even edit the data.